# Analysis of Highway Crack Maintenance: Outlining the Preventive Measures for Onsite Defects

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***Abstract*—Highway maintenance is crucial within transportation infrastructure because it directly affects the efficiency and safety of transit systems. Well-maintained highways reduce traffic, lower accident risks, and boost economic growth by ensuring the smooth transport of goods and people. As transportation needs change, using advanced maintenance strategies, like road maintenance outsourcing, has become vital for road authorities. These strategies help optimize resource allocation and improve service delivery. While these strategies offer potential benefits, research shows conflicting views on their actual effectiveness. Because of this, a full evaluation of how they're put into action is needed. Additionally, keeping up with highway maintenance is key as technology and traveler expectations change. An interactive and personalized approach can really improve the user experience and make travel decisions easier.**

***Index Terms*—PQC, DLC, Sealant, Water Penetration, Cracks, Polysulphide.**

## I. INTRODUCTION

A robust transportation system is essential for a nation's rapid economic and social progress. Failures in roads can manifest in various forms, including water bleeding, cracks, depressions, edge subsidence, rutting, edge damage, localized aggregate loss, potholes, and scoop outs. Pavement design aims to accommodate future traffic, which typically grows over time. However, predicting future traffic growth isn't always precise, affecting the accuracy of forecasting pavement performance and, consequently, its designed lifespan. Potential causes of road failures include inadequate quality properties of bituminous mixes, the impact of overloading vehicles, poor drainage conditions, and natural disasters. Furthermore, the area of failure progressively expands due to a lack of appropriate and timely maintenance. While rigid pavements are generally more durable, they can be less adaptable to temperature-related expansion and contraction. Predominantly, the decision to use flexible or rigid pavement depends on several factors, such as volume of the traffic, environmental conditions, and monetary budgets. Each pavement type offers definite advantages and disadvantages, and engineers choose the most suitable design according to the specified needs of each road or highway project

## II. LITERATURE

The "pavement" typically refers to just the surface layer, in highway design, it encompasses the total thickness, including the surface, base, and sub-base. What we're discussing relates to roads or pavements, which are constructed with layered materials to offer a stable, even surface for vehicles and distribute the load to the natural soil subgrade. Flexible pavements, like asphalt roads, are more prone cracks, rutting, and potholes because of weather change and heavy traffic volume.

Highways are indispensable for economic expansion by enabling well organized transportation of goods and merchandise. They connect business to markets, promote trade, and support regional development. Additionally, highways connect urban centers, rural areas, and industrial zones. This allows us to pinpoint maintenance practices that not only minimize environmental impacts and enhance energy efficiency but also foster sustainable transportation systems, contributing to broader sustainable development goals across environmental, social, and economic dimensions.

The economic implications of highway maintenance extend far beyond simple upkeep, significantly influencing transportation efficiency and infrastructure sustainability. Well-maintained highways facilitate smoother traffic flow, reducing travel time and vehicle operating costs, and enhancing motorists' safety, which

lowers accident-related expenses. Additionally, efficient highway systems are crucial for timely deliveries and overall supply chain management, especially as consumers rely more on e-commerce. This is a factor often overlooked in traditional economic assessments.

## III. WATER PENETRATION

Water intrusion significantly impacts road stability. Increased water penetration into cracked PQC elevates the risk of base layer instability. Water infiltrates through the PQC cracks and reaches the DLC (Dry Lean Concrete). Given DLC's lower water content, this penetration compromises its load-bearing capacity, destabilizing the PQC layer's base. While considering the cracks in DLC it should be strictly replaced. Negligence to the DLC cracks leads to the pavement failure. More the DLC loss its load bearing capacity wider and deeper the crack gets.

The development of cracks in the Dry Lean Concrete (DLC) should be addressed promptly to prevent pavement failure. Neglecting these cracks can diminish the DLC's load-bearing capacity, exacerbating the cracking

Common methods such as pouring cement slurry or injection grouting are ineffective because they can lead to water penetration into the DLC layer. The purpose of the separation membrane, specifically the LDPE (Low-Density Polyethylene) sheet, is to prevent moisture infiltration into the DLC layer.

Keeping the track of the major and moderated cracks is important because the penetration of the water or other foreign material can led to the instability of the pavement.

As anticipated, an increase in the water-cement ratio leads to a corresponding rise in the coefficient of capillary penetration into concrete. Cracks filled with water serve as internal water sources, facilitating further penetration into the porous material beyond the cracks and perpendicular to the crack surface.

## IV. DEFECTS AND THERE TIMELINE

Early treatment of the defects is necessary as its prevents the situation getting worse. During the site inspection the defects of the pavement should be adhere on the urgent and emergency basis. The severity of the crack increases 2 times that of time.

TABLE I. DEFECTS AND TIME OF THERE RECTIFICATIONS

| Sr. No | *Types of Defects* | *Timeline for Defect* | *Nature of Severity* |
|---|---|---|---|
| 1 | Breach / Blockade | 24 hours | High |
| 2 | Moderate Cracks | 10 days | High |
| 3 | Major Cracks | 5 Days | Severe |
| 4 | Pothole /Settlement | 5 | High |
| 5 | Other Pavement Defects | 10 days | Low |

To streamline our workflow, we can simultaneously address defect identification, execution, and timeline monitoring. Here's a simplified schedule for addressing the cracks, organized by month:

TABLE II. DEFECTS RECTIFICATIONS ACCORDING TO THE MONTH

| Sr. No | Month of Rectifications | Activity | Remark |
|---|---|---|---|
| 1 | March to June | Sealing | Highly Preferable. (Due to hot temperature the curing time can be reduced) |
| 2 | June to September | No Activity | Due to Rain no activity should be carried out. |
| 3 | Septembe r to March | Stitchin g of PQC | Stitching should be carried out as the tendency of concrete to contract can help the crack expansion. |

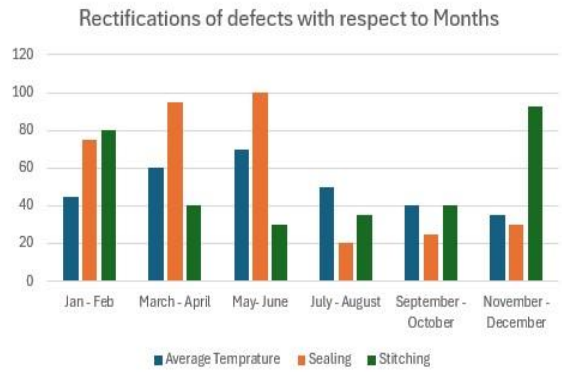


Fig. 1. Relation of temeprature with respect to PQC rectfication with sealing and stitching

Especially the month of March to May is purely suitable for Crack Sealing as the concrete expands in the summer. While the month of November to February is suitable for stitching of the PQC as the concrete contracts the gap between the two layers is reduced and the crack groove can be stitched together.

## V. WEARING OF THE POLYMER BASE SEALENT

Fig. 2. Wear and tear of the polymer base epoxy sealent and cementious grouting

- Sealant wear and tear occurs when the sealant level exceeds that of the PQC (Pavement Quality Concrete). The tires of heavily loaded vehicles then create friction, transferring the load to the DLC (Dry Lean Concrete) and underlying layers.
- Epoxy sealants have several limitations: they can degrade or yellow when exposed to UV light for extended periods, some formulations require many hours or even days to fully cure (which can slow down project timelines), cured epoxy can be rigid and prone to cracking under heavy flexing or impact (unless modified), and they tend to be more expensive than alternatives like silicone or polyurethane. Additionally, uncured epoxy may release irritating fumes and cause skin or respiratory irritation, necessitating the use of PPE such as gloves, masks, and adequate ventilation.

## VI. USING OF POLYSULPHIDE BASE SEALENT.

Withstands exposure to fuels, oils, solvents, and many chemicals. Remains flexible after curing, accommodating movement and thermal expansion/contraction in joints. Offers excellent waterproof seals. Withstands exposure to sunlight and harsh weather without degrading. Long service life (often 15–20+ years) with resistance to aging, cracking, and shrinkage. Bonds well to concrete.

Fig. 3. Sealing of the cracks with Poilysulphide base sealents

To ensure effective crack sealing, please adhere to the following guidelines:

- Seal cracks exclusively with Polysulphide-based sealant.
- Avoid extra groove cutting or chipping of the crack, as this can lead to its expansion.
- Refrain from using hard substances like polymer epoxy resin, as their hardness after drying can be problematic.
- Be aware that epoxy hardeners can disrupt the concrete's natural expansion and contraction cycle during summer and winter.
- The sealant should be poured into the crack at once. No joints or bubbles should be encouraged inside the crack.
- Avoid the stitching of Hair crack as it does not affect the stability of the pavement in early stage. (Note: The Hair crack does not have enough depth to penetrate the water to DLC layer.

TABLE III. CRACK TREATMENTS

| Sr. No | *Types of Cracks* | *Width (mm)* | *Depth (mm)* | *Recommendations* |
|---|---|---|---|---|
| 1 | Hair Crack/ Surface Crack | 0.05 to 3 | 5 | No Treatment / under Observations |
| 2 | Minor Crack | 3 to 6 | 10 to 50 | Only sealing to be done with low viscosity epoxy |
| 3 | Moderate | 6 to 15 | 50 to 300 | Stitching and sealing to be done with Polysulphide rubber base sealant. |
| 4 | Major Crack | 15 + | 300 + | The panel should be replaced (FDR). |

## VII. OVERLAYING OF THE SURFACE.

Fig. 4. Ovcr Laying of Bitmine Concrte layer on the PQC

The figure above illustrates the application of Bitumen Concrete Patch work on a Paved Quality Concrete Surface. The use of Bitumen Concrete prevents water from penetrating cracks and reaching the DLC and lower layers, and it typically lasts for 5 to 10 years depending on traffic volume. The surface finish of the Bitumen Concrete layer should match that of the PQC (Pavement Quality Concrete).

For enhancing surface performance, applying a layer of Bituminous Concrete (BC) is more cost-effective than replacing the existing concrete. BC provides thermal insulation and absorbs vehicle noise, which bare concrete struggles to do effectively. Furthermore, BC offers enhanced grip in wet conditions, particularly when high-quality aggregates are incorporated into the mix. The application of BC is also quicker, allowing the road to be opened to traffic sooner compared to concrete repairs or replacements. The smoother surface of bituminous concrete reduces vibrations and noise, thereby increasing driver comfort. Effective bonding can be achieved through the application of a tack coat.

## VIII. CONCLUSION

Drivers expect a comfortable journey, free from excessive bumps, rutting, or uneven surfaces. The absence of potholes, cracks, and rough patches is essential, particularly for long-distance and high-speed travel. Adequate grip is necessary to maintain control, even in wet conditions or during sudden braking. Pavements should be free of loose materials like gravel that could lead to accidents or vehicle damage. Pavements should be durable enough to avoid frequent repairs, which minimizes traffic disruptions and public expenses.

Effective cross slopes and drainage systems are needed to prevent water accumulation on the pavement surface. A clean, black (asphalt) or well-finished (concrete) pavement enhances the overall impression of quality and maintenance.

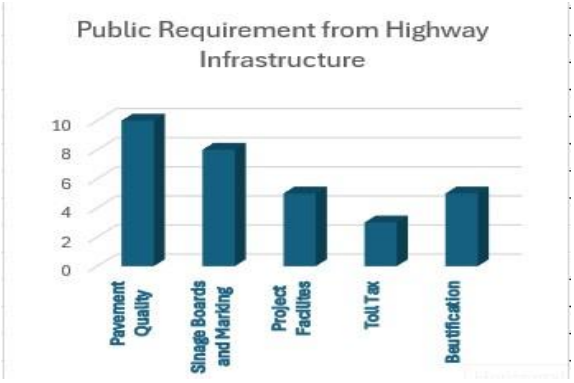


Fig. 5. Public requiremnt from the Highway Maintenace

In conclusion, highways and their maintenance play a crucial role in the field of Engineering. They are crucial for economic growth, enabling the efficient transport of goods, services, and people between different areas. It is logical that the purpose of highway construction is to provide a firm and even surface for the carriageway or pavement that can withstand the stress caused by numerous load applications, thus increasing the lifespan of the road. Based on data collected from road construction and maintenance authorities, most road maintenance work is done on an emergency basis. The failure of roads can often be attributed to inadequate material quality and quantity, as well as design flaws.
Across the world the Pavement defects are never ending. The better quality of the pavement while construction can reduce the maintenance cost after on. The performance of the Pavement quality directly affects the rate of accidents caused.

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